

Self-Adhesive Preapplied Electrode Pads for Defibrillation and Cardioversion

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The efficacy of self-adhesive electrode pads for defibrillation and cardioversion was assessed in 80 patients who received 267 shocks from self-adhesive pads. In all but two patients, defibrillation or cardioversion was achieved at least once. The pads were equally effective when used in the apex-anterior or apex-posterior position. The transthoracic impedance using self-adhesive pads was 75

± 21 ohms (mean \pm standard deviation), which is similar to previously reported transthoracic impedance in defibrillation, using standard hand-held electrode paddles of 67 ± 36 ohms. It is concluded that self-adhesive electrode pads are effective for defibrillation and cardioversion.

Current defibrillation techniques require the application of hand-held, paddle-shaped electrodes to the chest. Although electric shocks to terminate cardiac arrhythmias are effective, the technique of electrode application does have some disadvantages. The operator requires unimpeded access to the patient's chest to apply the paddle electrodes. The paddles must be well coated with a coupling agent before use; if the gel or paste used for this purpose is inadvertently spread across the chest, the current may follow this low resistance pathway rather than traversing the thorax and heart. Because the paddles are placed on the chest after the patient has developed ventricular fibrillation and rapid treatment is crucial, haste may cause serious errors of paddle electrode placement. This may result in reduced intracardiac current flow and failure to depolarize an adequate amount of myocardium to achieve defibrillation (1-3). A major source of defibrillation failure is incorrect paddle electrode placement (4); in one study (5), placement was erroneous in 35% of the patients.

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Self-adhesive electrode pads for defibrillation have been suggested (6). Such pads, preapplied in calm circumstances, might overcome most of the disadvantages of hasty, often erroneous placement. However, because no pressure is applied to self-adhesive electrode pads, their potential advantages might be overbalanced by a high impedance (7). A preliminary evaluation of shocks from self-adhesive electrode pads was conducted in animals during sinus rhythm by Ewy et al. (8), who found a higher impedance with the pads. The purpose of our study was to evaluate the efficacy of self-adhesive preapplied monitor-defibrillator electrode pads for defibrillation and cardioversion in human beings.

Methods

Self-adhesive electrode pads. The pads evaluated in these studies consisted of foil electrodes covered by stannous chloride pre-gelled pads as the interface between the electrode and the chest wall (Fig. 1). The backing was nonconductive, and had an adhesive outer ring (R2 Corporation). When applied, only the nonconductive backing was visible externally; there was no exposed metal.

Patients. Clinical data were collected prospectively from patients undergoing elective cardioversion and emergency defibrillation at the University of Iowa Hospital from March 1982 to August 1983. The study was approved by the University of Iowa Human Research Committee. Criteria for

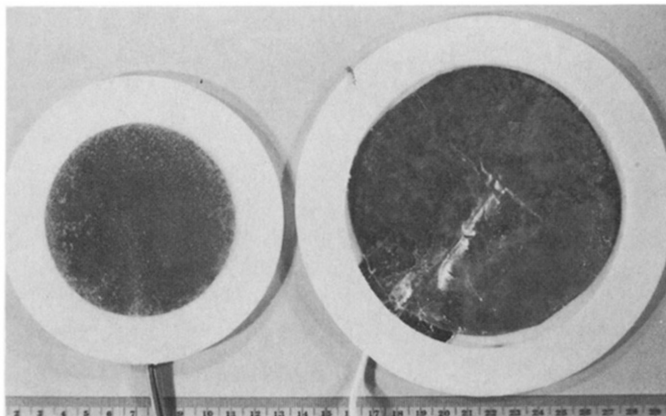


Figure 1. Self-adhesive electrode pads as viewed from the side applied to the chest. The **light outer rim** is a nonconductive backing coated with an adhesive material; the **darker central section** of the left-sided pad consists of stannous chloride gel covering a foil electrode. The gel has been removed from the pad to the right, revealing the foil electrode. The smaller pad (**left**) was always placed over the cardiac apex; the larger pad (**right**) was placed either adjacent to the right upper sternum (apex-anterior pad position) or in the right infrascapular area (apex-posterior pad position).

inclusion were simply the need for elective cardioversion or emergency defibrillation, willingness to participate (patients undergoing elective cardioversion), or wearing the electrode pads at the time spontaneous ventricular fibrillation or tachycardia occurred.

Study protocol. We attempted to use the pads on all patients undergoing cardioversion or defibrillation during this period, but did not try to apply the pads to patients if ventricular fibrillation had already begun, because this might have caused an unacceptable delay in defibrillation. Three different defibrillators were used to deliver shocks: PhysioControl Lifepak 6, Hewlett-Packard model 78660B and Datascope MD2J. The elective cardioversions were performed in the coronary care unit or on an adjacent cardiology ward. Defibrillation data were obtained from patients at high risk with acute infarction or arrhythmia, or both, (who developed spontaneous ventricular fibrillation or ventricular tachycardia) in the coronary care unit and medical intensive care unit and from patients with a history of severe arrhythmia who were undergoing provocative electrophysiologic studies in which ventricular tachycardia or ventricular fibrillation, or both, was provoked by electrical stimulation.

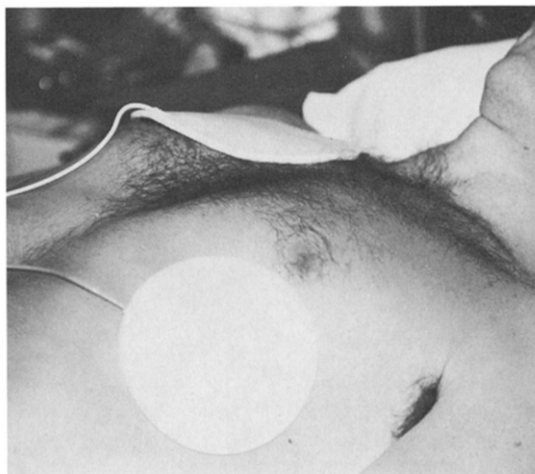
Two different electrode pad positions were used and compared in patients: apex-posterior and apex-anterior. In the apex-posterior position, the apex pad (8 cm in diameter) covered the palpable cardiac apex while the posterior pad (12 cm) was placed in the right infrascapular area, one or two interspaces more cephalad than the apex pad. In the apex-anterior position, the apex pad (8 cm in diameter) again covered the cardiac apex, while the anterior pad (12 cm)

was placed just under the right clavicle adjacent to the right upper sternum (Fig 2). The apex-posterior position was used from March to September 1982; after this date, apex-anterior position was used for comparison. However, if a patient had previously received shocks from one position and another cardioversion or provocative electrophysiology study was undertaken, the pads were placed in the other position so data from both positions could be obtained.

The following delivered energy protocols were recommended, based on generally accepted clinical recommendations (1, 9-12): for cardioversion of atrial fibrillation, an initial synchronized shock of 100 joules was given and followed, if necessary, by a second shock of 200 joules and then, if necessary, a shock of 300 and of 400 joules. For atrial flutter, we initially administered 20 joules, then, if necessary, 40, 100, 200 joules, and so forth. For ventricular tachycardia, we began at 100 joules, then administered 200 joules and so forth. For ventricular fibrillation we used 200 joules initially, then 300 and 400 joules. All energies are expressed as delivered energy, using the standard clinical assumption of a 50 ohm impedance (7). After it became clear that most shocks given at these recommended levels were successful (see Results), the physicians selecting the energies were advised that they could, at their discretion, reduce the energy of initial or subsequent shocks. In this way, we obtained data on the efficacy of self-adhesive electrode pads for defibrillation and cardioversion with low-energy shocks. However, no systematic attempt was made to determine the lowest energy possible for defibrillation or cardioversion with self-adhesive pads.

Peak current flow was displayed and transthoracic impedance was calculated using previously described methods (7). Briefly, the defibrillator was fired into known impedances (15 to 150 ohms) at delivered energies of 10, 20, 40, 75, 100, 150, 200, 300 and 400 joules. Peak current

Figure 2. Self-adhesive electrode pads in an apex-anterior orientation on a patient.



flow was noted, and current versus impedance curves were constructed for each energy used. Subsequently, knowing the energy selected in the patient and the peak transthoracic current resulting from that energy enabled us to determine the transthoracic impedance for each shock by referring to the previously constructed curves.

Statistical analysis. Comparisons of percent success rates between the self-adhesive electrode pad positions (apex-posterior versus apex-anterior) were done by chi-square test. Comparisons of transthoracic impedance were done by Student's *t* test. All data are expressed as mean \pm 1 standard deviation.

Results

A total of 80 patients received 267 shocks from self-adhesive electrode pads. The data from shocks given for ventricular fibrillation and tachycardia are summarized in Table 1; the data from cardioversions of atrial fibrillation and atrial flutter are summarized in Table 2.

Shocks for ventricular arrhythmia. In all 23 patients receiving shocks for the most serious arrhythmia, ventricular fibrillation, defibrillation was successful at least once. Eleven patients received *initial* shocks of 150 to 200 joules and in 7 (64%) of these 11, defibrillation occurred with the first shock. Cardioversion was successful in every patient with ventricular tachycardia. Shocks of 100 joules for ventricular tachycardia were 89% successful in achieving sinus rhythm. In a few patients, we attempted to determine the minimal energy level that could convert ventricular tachycardia; shocks

of less than 100 joules for ventricular tachycardia recorded an overall success rate of 84% and achieved sinus rhythm at delivered energies as low as 10 joules in one patient.

Shocks for atrial arrhythmias. Atrial fibrillation was converted to sinus rhythm with use of self-adhesive pads in all patients but two at energy levels of 100 to 250 joules; in one patient cardioversion was unsuccessful with three shocks (100 to 300 joules) and in one patient it was unsuccessful with four shocks (100 to 400 joules). We did not attempt cardioversion with standard hand-held electrode paddles after cardioversion with self-adhesive pads failed in these two patients. In one patient with paroxysmal atrial tachycardia with 2:1 atrioventricular block, cardioversion to sinus rhythm occurred with one shock of 100 joules.

Pad orientation. The overall success rates of shocks from either pad orientation were similar, as shown in the tables. First-shock impedance data were obtained on 68 patients. The mean first-shock transthoracic impedance was 75 ± 21 ohms (range 28 to 150). Impedance for apex-anterior pads was 79 ± 26 ohms; for apex-posterior pads it was 73 ± 16 ohms (probability [p] = not significant [NS]).

Discussion

Effectiveness of self-adhesive pads for defibrillation. This study demonstrates that self-adhesive preapplied monitor-defibrillator pads are effective for defibrillation and cardioversion. The success rates of shocks from self-adhesive pads for ventricular and atrial arrhythmias were sim-

Table 1. Energy Requirements for Cardioversion of Ventricular Arrhythmias

A. Ventricular Fibrillation									
	Number of Patients	100 Joules		200 Joules		300 Joules		400 Joules	
		Total Shocks	Successful Shocks	Total Shocks	Successful Shocks	Total Shocks	Successful Shocks	Total Shocks	Successful Shocks
Apex-anterior self-adhesive pads	14	5	1	21 [†]	14	3	1	8	6
Apex-posterior self-adhesive pads	12	12	6	15 [†]	11 [†]	—	—	1 [‡]	1 [‡]
Total	23*	17	7	36	25	3	1	9	7
B. Ventricular Tachycardia									
	Number of Patients	< 100 Joules		100 Joules		200 Joules			
		Total Shocks	Successful Shocks	Total Shocks	Successful Shocks	Total Shocks	Successful Shocks	Total Shocks	Successful Shocks
Apex-anterior self-adhesive pads	24	12	11	22	20	48§	41§		
Apex-posterior self-adhesive pads	26	13	10	25	22	15	12		
Total	47*	25	21	47	42	63	53		

*Three patients received shocks from both pad positions; [†] includes two shocks at 150 joules; [‡] used 360 joules; [§] includes one patient who received 27 shocks, of which 24 resulted in cardioversion.

None of the apex-anterior vs. apex-posterior comparisons at individual energy levels are significantly different.

Table 2. Energy Requirements for Cardioversion of Atrial Arrhythmias

A. Atrial Fibrillation									
	Number of Patients	100 Joules		200 Joules		250 or 300 Joules		400 Joules	
		Total Shocks	Successful Shocks	Total Shocks	Successful Shocks	Total Shocks	Successful Shocks	Total Shocks	Successful Shocks
Apex-anterior self-adhesive pads	14	13	7	6	4	—	—	—	—
Apex-posterior self-adhesive pads	15	18	10	10	4	4	1	2	1
Totals	27*	31	17	16	8	4	1	2	1

B. Atrial Flutter							
	Number of Patients	< 100 Joules			100 Joules		
		Total Shocks	To NSR	To Atrial Fib	Total Shocks	To NSR	To Atrial Fib
Apex-anterior self-adhesive pads	6	9	5	3	1	1	—
Apex-posterior self-adhesive pads	5	5	1	3	1	1	—
Totals	11	14	6	6	2	2	—

*Two patients received shocks from both pad positions. None of the apex-anterior vs. apex-posterior comparisons at individual energy levels are significantly different.

ilar to those previously reported using standard paddle electrodes.

Our initial shock success rate of 64% for ventricular fibrillation using 150 to 200 joules is very similar to the defibrillation rates achieved in the large prospective study of Weaver et al. (11), who used initial energies of 175 joules in patients with out of hospital cardiac arrest and achieved first-shock defibrillation in 61% of patients. Every patient with ventricular fibrillation we studied had at least one successful defibrillation. We did find that the energy used for the shocks with electrode pads should not be less than 150 to 200 joules: at 100 joules only 7 (41%) of 17 shocks achieved defibrillation. Thus, the present generally accepted recommendations (1,11) for initial shock energies of 200 joules for ventricular fibrillation would be appropriate for self-adhesive electrode pads as well as for standard electrode paddles.

For atrial arrhythmias, our results with self-adhesive pads are also very similar to clinical experience using standard electrode paddles. For example, using the same energy protocols as in the present study, we previously reported (10) that with standard paddle electrodes, cardioversion occurred in 103 (93%) of 111 patients with atrial fibrillation—identical to the 93% rate (25 of 27) of successful cardioversion of patients with atrial fibrillation using the self-adhesive pads in this study. Similarly, with standard paddles cardioversion occurred in all 62 patients with atrial flutter in our previous study (10); in the present study with self-adhesive pads, cardioversion occurred in all 11 patients with atrial flutter.

Transthoracic impedance. Ewy et al. (8) found a higher transthoracic impedance in dogs in sinus rhythm when dis-

posable electrode pads were compared with standard defibrillator paddle electrodes. In our study, the mean transthoracic impedance of first shocks given for ventricular arrhythmias using self-adhesive electrode pads was 75 ± 21 ohms (range 36 to 150). This is similar to the impedance we have previously reported (7) using standard size electrode paddles for ventricular defibrillation: 67 ± 36 ohms (range 16 to 143). Two factors help to reduce impedance when using these pads. When the pads are in the apex-posterior position, the weight of the patient's torso provides high pressure and probably improves pad-skin contact on the posterior pad. In addition, we used pairs of pads consisting of one 8 cm and one 12 cm diameter pad; the larger pad provides a greater surface area that also tends to reduce impedance (7,12).

Electrode pad position. Is the position of the electrode pads on the thorax important in defibrillation and cardioversion? Theoretical considerations must include interelectrode distance (7), electrode-skin contact (7), myocardial and pulmonary resistivity (13,14) and the directional vector of intracardiac current flow. In this study, the first-shock transthoracic resistance of pads using apex-anterior and apex-posterior positions were very similar: 79 ± 26 versus 73 ± 16 ohms, respectively ($p = \text{NS}$). We found similar success rates of shocks given from apex-anterior versus apex-posterior positions for atrial and ventricular arrhythmias. In all patients with ventricular fibrillation or ventricular tachycardia, defibrillation or cardioversion occurred at least once with pads placed in either apex-anterior or apex-posterior positions. Using 200 joules energy, 14 (67%) of 21 shocks from apex-anterior pads resulted in defibrillation compared with 11 (73%) of 15 shocks from apex-posterior

pads ($p = \text{NS}$). Three patients with ventricular fibrillation received shocks on different days from both apex-posterior and apex-anterior positions; in each of these individuals, shocks of 200 joules defibrillated from *either* pad position. The two patients in the study without at least one successful cardioversion or defibrillation received shocks for atrial fibrillation from apex-posterior pads. Overall, we found no reason to prefer one pad position over the other; both are effective.

Disadvantages of pads. Half of our patients with ventricular arrhythmia received shocks from pads while in the coronary care unit. We encountered some logistic problems when pads were applied for more than 3 hours in these patients. We arbitrarily adopted a policy of changing pads at least daily. Despite this, we found that some of the pads demonstrated cracking of the foil, crimping and folding of the backing and partial loss of adhesiveness. This was particularly noticeable in patients who were restless or diaphoretic. A potentially serious situation could exist if a posteriorly placed pad became partially or completely detached from the patient; in such a case, partial or complete loss of pad-skin contact would occur, which could result in little or no current flow traversing the chest and failure to defibrillate. Moreover, at the same time the detached pad could be concealed under the patient, delaying recognition of the problem. We did encounter several partial or complete posterior pad detachments. Fortunately no shocks were delivered in such a case. This potential problem suggests an advantage of apex-anterior over apex-posterior pad placement; because apex-anterior pads would be visible, detachment of a pad would be quickly noticed and corrected.

In coronary care unit use, we also found that the pads interfered to some degree with physical examination of the heart and with 12 lead electrocardiograms. The pads were also visible on routine chest X-ray films. Temporary removal of the pads for physical examinations, electrocardiographic recordings or chest X-ray films was often necessary, requiring replacement with a new set.

Advantages of pads. The drawbacks of self-adhesive pads in coronary care unit use must be weighed against the advantages of accurate electrode placement. Another advantage of the pads in the coronary care unit is that their relatively large size results in a very stable, high quality electrocardiogram for monitoring purposes. Although we did not test the pads in out of hospital settings, they should also be useful in ambulance transportation, where access to the patient may be limited or difficult. Finally, these pads increase the safety of the operator by allowing him or her to stand well away from the patient and bed, thus eliminating the chance of an accidental shock to the operator.

We found the electrode pads to be especially convenient and helpful in the electrophysiology laboratory, for patients who are likely to develop ventricular tachycardia or fibrillation. When using standard paddle electrodes to cardiovert

or defibrillate, it is necessary to remove sterile drapes, push aside the fluoroscopy tube and apply electrode paddles. All of these procedures may delay defibrillation, and all are eliminated when preapplied self-adhesive pads are used. The pads could also be used during cineangiographic studies. However, although they are sufficiently radiolucent to permit viewing of catheters for manipulation, they may obscure fine angiographic detail.

The maximal number of shocks that may be administered through one set of pads is unknown. One of our patients received, through one set of pads, a total of 27 shocks for recurrent ventricular tachycardia during a 2 hour period. Twenty-four of these shocks were successful. The present cost of the pads is \$5.25 per set.

Complications. No major complications were encountered in use of the electrode pads. One patient developed a pruritic, morbilliform eruption after wearing the pads for 1 day (no shocks were given). This resolved quickly after use of the pads was discontinued. Ring-shaped erythematous areas were usually evident after shocks were given using pads; their appearance was similar to the erythema generally seen after shocks from standard paddle electrodes. No patient complained of severe pain or discomfort at these sites.

Conclusions. We found preapplied self-adhesive, monitor-defibrillator pads to be safe and effective for defibrillation and cardioversion. They should be especially useful for short-term use in the electrophysiology laboratory and in transportation of the high-risk patient with cardiac disease.

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